Adaptation of Radiology Software to Improve Cardiology Results Reporting

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Keywords

Pediatrics, Ambulatory care information systems, Electronic Health Records, Clinical Care, Quality Improvement

Summary

Objective: Twenty-four hour ambulatory electrocardiograms ("Holter" monitors) are a key diagnostic test in cardiology. Commercial electronic medical record (EMR) tools have not been designed for pediatric Holter monitor reporting and paper-based methods are inefficient.

Methods: Our tertiary pediatric hospital adapted a radiology EMR tool to a cardiology workflow in order to report Holter monitor results. A retrospective review was performed at 4 time points: prior to intervention, immediately post-intervention, at 6 months and at 12 months post-intervention. The primary outcome variable was time to reporting of Holter findings.

Results: Holter reports were reviewed on 527 studies (patient ages: 1 day to 42 years). The time between the date the patient returned the Holter monitor until the date the referring physician received a final report improved from 19.8 days to 1.5 days ($p<0.001$). This result was durable over the next 12 months of follow-up. Physician interpretation time improved from 2.1 days to 0.6 days ($p=0.01$). Transcriptionist time and result scanning time were eliminated (removing 1.9 days and 14 days from the workflow, respectively).

Conclusion: EMR systems are not typically designed for pediatric cardiology, but existing systems can be adapted, yielding important gains for patient care. In specialties like pediatric cardiology, there is insufficient volume nationally to drive development of commercial systems. This study demonstrates the general principle that creative adaptation of EMR systems can improve result reporting in pediatric cardiology and likely in other cardiology practices.

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1.Background and Significance

Twenty-four hour cardiac rhythm monitors ("Holter monitors") are ambulatory monitors that record a continuous electrocardiographic tracing. The monitors are small, portable devices (non-invasive electrodes taped to the patient's chest and a small computer). The surface electrograms are processed by a technician to generate summary data and representative tracings. A cardiologist interprets the summary data and trends, then issues a final report. The ordering physician receives the report for use in patient care. In pediatrics, clinical indications for Holter monitors include rhythm-symptom correlation, monitoring of medication efficacy, and identification of arrhythmias [2–6]. Abnormal Holter results contain important information for patient care, including suggesting an elevated risk for sudden cardiac death in some settings [7, 8]. The prompt delivery of the results to the ordering physician has benefits to the physician, to the hospital and to the patient.

1.1 Local problem

In our center, return of Holter results was taking too long from the time a Holter was returned by the patient until the time that the ordering physician received a written report. Delays in returning results to physicians had the potential to lead to poor patient outcomes.

Proprietary systems for electronic Holter interpretation exist, but they require a major investment in information technologies infrastructure for implementation [9]. Our hospital uses the EPIC® electronic health record (EHR) system (Epic Systems Corporation, Verona, WI). EPIC collects and stores clinical results, then distributes report to ordering physicians. No reading or processing system for Holter reading and interpretation was available in our EPIC build. However, EPIC has a mature software product for evaluating and reporting radiology results (the Radiant Radiology Information System).

2.Objectives

The aim of this project was to adapt a radiology EHR product for reporting of Holter monitor results. Our primary goal was to decrease the duration between the date that the patient returned his or her Holter monitor to our institution and the date that his or her ordering physician received a final report. From a clinical standpoint, our mean turnaround time at baseline was approximately 20 days. This generated concern that clinical follow-up might be overly delayed and was a stressor on patient-physician relationships [10]. From an administrative standpoint, the extensive paper-based system created inefficiencies in storage, communication, and personnel time management.

We saw parallel workflows in cardiovascular Holter monitoring and the radiology department. In both departments, a study is initiated by an electronic order. The study is performed and additional technical processing is required prior to interpretation. A physician who does not have direct clinical responsibility for the patient performs the interpretation and the final report needs to be delivered quickly and efficiently to the ordering physician. We generated the hypothesis that adapting a radiology EHR system to use in cardiology would produce a shorter turn-around time, using fewer resources than implementing a proprietary electronic Holter results system.

3.Methods

This quality improvement project was implemented in a tertiary children's referral hospital. Holter monitors are processed at our facility ("Main Processing") and at a subcontractor ("Outside processing", MedNet Healthcare Technologies, Ewing, NJ). The outside subcontractor performs the scanning function that our technician would normally perform and does not otherwise alter the workflow. Our team consists of 4 electrophysiologists and 10 ECG technicians, plus an administrative hospital leader who supervises the technicians. Our initial step was value stream mapping (VSM), followed by establishing a reading template in serial Plan-Do-Check-Act (PDCA) cycles (see section 3.2) and then a final digital implementation strategy. A back-up system was in place to default back

to the original reading method if necessary during the workflow transition. We have an independent process to identify "urgent" or "emergent" clinical findings on Holter. Urgent or emergent clinical findings trigger rapid notification to an electrophysiologist and the ordering physician. This system remained in place both before and after implementation and was not altered by the QI process described here.

3.1 Existing Workflow

See ▶Figure 1A for a diagram of our workflow procedures prior to the intervention, established in our initial VSM sessions. In summary, a combination of electronic transmission, paper-based interpretation, transcription, and manual log procedures were required to successfully deliver a Holter monitor result. Holter tracings were interpreted by a physician with the aid of a paper-based "Reading Template", a semi-structured reading tool with blanks left for numerical data and physician interpretation (Online Supplement 1). The result was available in the medical record, but the ordering physician did not receive notification that the result was available.

We identified four primary inefficiencies in this system. First, the reliance on paper-based summary reports and a paper template system required multiple person-to-person transfers of the Holter monitor tracings. Second, the step of using a transcriptionist to type the interpretation on a report was time-consuming, prone to introducing inadvertent errors, and expensive. Third, the process of scanning a paper report to the EHR was time-consuming. Fourth, ordering physicians did not receive notification of results when a report was available.

3.2 New Workflow

Using the radiology reading template software, the paper template was converted to a digital document and spaces for handwritten notes were converted to drop-down multiple selection lists, plus space for unstructured interpretation. A core team consisting of one ECG technician, one physician and one IT analyst created a digital template based on the original paper template. The template underwent four PDCA cycles in a test environment until we had obtained consensus on a digital template. Our information management professionals implemented the final version of the digital template in our EHR system, using RadiantTM software.

Once the new template was available, we implemented the final workflow shown in ▶Figure 1B. Reports were signed electronically and the results in digital form were immediately routed to the ordering physician. In addition, the logbook that was kept on paper by technicians could be digitally generated after implementation of the new workflow.

3.3 Information Technologies Investment

The template required 50 person-hours encode and test. Custom software was not required; all programming was done with the tools that were provided with EPIC. Coordination with the technical support team from the Epic Systems Corporation was not required.

3.4 Analysis

Outcome measures were determined prior to study initiation. We pre-specified 100 Holters for analysis at each time point, with a higher number of Holters 6 months after implementation because we anticipated that this was the critical time point for sustainable results. Holter monitors were excluded from analysis if there was significant loss of data or other technical issues (6/533, 0.01%). In advance, we identified 6 data collection points in the process for each Holter monitor: the date that the Holter monitor was placed on the patient, the date it was returned to us by the patient, the date that the technician delivered the Holter data packet to the physician, the date that the physician finished the interpretation, the date the transcriptionist finished processing the data and the date that the final report was available in our EHR. With this data, four key outcome measures could be identified:

Total Time: The Total Time was the time elapsed in days between the date the patient returned the Holter monitor and the date the ordering physician had access to a final report. This was our primary outcome measure.

Physician Interpretation Time: The Physician Interpretation Time was the time in days elapsed between the date the technician made the Holter data available to the physician until the date the physician signed a final report.

Technician Scanning Time: The Technician Scanning Time was the time elapsed in days between the date the patient returned the Holter monitor until the date the technician made the data available to the physician for reading.

Patient Return Time: The Patient Return Time was the time elapsed in days between the date the patient received a Holter and the time the family returned the Holter to the hospital.

Differences in time intervals were analyzed by t-test and corrected for multiple comparisons with the Bonferroni method. Stata 12.1 was used for data analysis and creation of figures (StataCorp, College Station, TX).

4. Results

A retrospective review of 527 Holter reports was performed. We evaluated 100 Holters prior to implementing our intervention. We evaluated the first 100 Holters immediately after the intervention was implemented. We evaluated 227 Holters 6 months after intervention. Finally, we evaluated 100 Holters 1 year after intervention.

The mean age of patients at the time of Holter placement was 8.7 years (range 1 day of age – 42 years of age). Forty-nine percent of patients were female.

Before our intervention, the Total Time between the date the patient returned the Holter monitor until the date the ordering physician received a final report was 19.8 days (SD 42.3). Immediately after the intervention, the Total Time decreased to 1.5 days (SD 1.5, $p<0.001$). This result was durable over the next 12 months of follow-up (▶Figure 2).

There was a decrease in the Physician Interpretation Time with the new system (2.1 days versus 0.6 days, $p=0.01$, Figure 3). In addition, we eliminated the time that was required for the transcriptionist to type the interpretation based on the physician's handwritten notes (1.9 days, SD 2.6). The largest improvement in the workflow was eliminating the time between the completion of transcription and the final report being scanned into our EHR system. Prior to implementation of the new system, this scanning step required a mean of 14.0 days (SD 41.6). This workflow was entirely eliminated by the new system. We did not find any differences in Physician Interpretation Time between the 4 electrophysiologists involved in the project.

Technician Scanning Time did not change with the new system (1.8 days before implementation vs. 0.9 days after implementation, $p=0.55$). The Technician Scanning Time remained similar throughout the 12-month follow-up (▶Table 1). Patient Return Time did not change with the new system (4.1 vs. 3.8 days, $p>1$) or during follow-up (▶Table 1).

We reviewed additional Holters at the 6-month time point to allow internal comparisons. There was no difference in Total Time or Technician Scanning Time between the "Main Processing" Holters that were scanned internally our hospital and "Outside Processing" Holters that were scanned using an outside subcontractor (1.8 days vs. 1.6 days, $p=0.46$ for Total Time; 1.5 days vs. 1.8 days, $p= 0.62$ for Technician Scanning Time). "Outside Processing" Holters were associated with slightly longer Physician Interpretation Time durations than "Main Processing" Holters (0.9 days vs. 0.3 days, $p=0.001$).

5. Discussion

The primary finding of our quality improvement initiative is that a small investment in time can produce a substantial improvement in Holter monitor reporting efficiency using existing EHR technologies. Specialized software and expertise are not always required to improve physician workflow in EHR systems used for pediatric cardiology. We improved our primary outcome by implementing

changes to our technology configuration and by implementing changes in our personnel workflow, emphasizing the overlapping importance of both aspects of clinical data interpretation.

From a service perspective, non-invasive cardiology laboratories primarily care about our primary outcome measure, Total Time. Our intervention improved the Total Time by 18 days. This large improvement is a reflection of three smaller gains. First, we eliminated a time-consuming step of having our medical records department scan final reports into the EHR. By eliminating this single step, we removed an average of 14 days from our process – nearly the entire time savings. An important implication of the delay from the medical records department is the observation that cardiologists may not have operational control over all delays in Holter reporting. This study suggests that cardiologists may be able to implement internal cardiology systems that decreases the need to rely on other hospital systems.

Secondly, we eliminated the role of a transcriptionist in our workflow. This allowed the person who was previously employed in this role to be reassigned to other work, at a substantial ongoing cost savings for the hospital. Removing the transcription step accounted for another 1.9 days in time savings.

Physician Interpretation Time decreased by 1.5 days with implementation of the new system. Prior to implementation, physicians had been concerned that eliminating transcription and creating a direct-entry workflow would increase the workload on physicians and increase Physician Interpretation Time. Instead, we discovered that the automated worklist and the structured electronic reporting tool substantially improved physician workflow. Physician Interpretation Time reflects that amount of time that Holters spent in the physician work queue, as opposed to the time the physician spent interpreting each Holter. However, all 4 electrophysiologists felt subjectively that the modifications substantially improved their personal workflow for reading Holters. The time each physician spent with each Holter is an unmeasured variable.

The results of this intervention were durable. A common pattern for novel interventions is to demonstrate a burst of effectiveness at the time of implementation, followed by a regression to the mean as practitioners withdraw their intense focus from the new intervention. We found that our improvements were durable. We attribute this to the value stream mapping sessions during the planning phase, followed by four PDCA cycles of revision in the digital template prior to implementation, with buy-in from all stakeholders at each cycle. This allowed us to create a system that improved the workflow for each member of the team, even after the focus on this project dissipated and it became the routine method of Holter interpretation.

We found Patient Return Time and Technician Scanning Time did not change before and after the intervention. Neither of these processes were altered by the new workflow. We included these intervals as an internal control against an enhanced vigilance effect that might improve efficiency, even when workflows were unchanged. Only workflows affected by the new system improved. This suggests that the durable improvements are genuinely due to improved workflow and not due to a vigilance effect.

6. Limitation

This was a single institution study with only 4 electrophysiologists and 10 technicians using a single EMR system. Others may not achieve the same gains that we documented in our institution. However, the lessons of our experience may be relevant to many physicians who are searching for efficiencies in their practice.

7. Conclusions

EHR systems are not typically designed for pediatric cardiology workflow. However, aspects of these EHR systems can be adapted for cardiology with minimal investment of time and resources. These adapted systems can improve patient care. In specialties like pediatric cardiology, there is insufficient volume nationally to drive development of dedicated commercial systems. This study demon-

strates the general principle that creative adaptation of EHR systems can improve result reporting in pediatric sub-specialties.

8. Clinical Relevance Statement

It is not cost-effective or time-effective to design a custom EHR software product for every aspect of medical care. However, in many cases, EHR systems have designed other software solutions that can successfully adapted to improve results reporting for patients and clinicians.

Multiple Choice Questions

Which of the following correctly summarizes the reasons that an EHR system improved patient care in this study?

A. Decrease in total time between the patient returning the Holter and the final interpretation being available for review.
B. Increase in total time between the patient returning the Holter and the final interpretation being available for review.
C. Decrease in the technician scanning time required to process the Holter monitor for physician interpretation.
D. Decrease in billing errors due to improved ability to track the ordering physician and the reading physician's workflow.

Correct Answer: A. Patients returned their Holter monitor to the hospital and a final read was available to the ordering physician within 2 days. This improvement is a marked decrease in time from 19.8 days, which was the average total time before the intervention. There was no increase in time associated with our intervention (choice B). Technician scanning time did not change in our intervention (choice C). This is a reassuring finding since our automation did not alter the technician workflow, thus we demonstrate that the overall time changes are not due just to enhanced vigilance. Finally, we did not evaluate the rate of billing errors in this study (choice D).

What was the magnitude of change in the average total time saved per patient by instituting an EHR-based reporting system?

A. 18 hours.
B. 1 day.
C. 18 days.
D. 180 days.

Correct Answer: C. The average total time per patient decreased from 19.8 days to 1.5 days (a mean improvement of 18.3 days). While the actual improvement in each medical center may vary, the magnitude of the improvement in our center illustrates the value of moving away from paper-based reporting systems into online systems that can be accessed from any location.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Human Subjects

No human subjects were involved in this project. Institutional Review Board approval was obtained prior to preparation of this manuscript for publication.

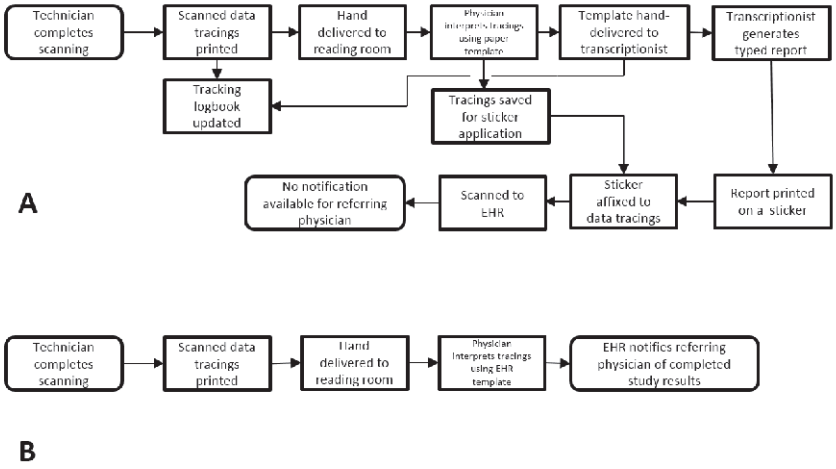

Fig. 1 Workflow Summary: Contrasts the workflow before implantation (panel A) against the workflow after implementation (panel B). The workflow summary in both A and B begins once the technician scanning completed. Until technician scanning is completed, the workflows are the same in two methods. EHR: Electronic Health Record.

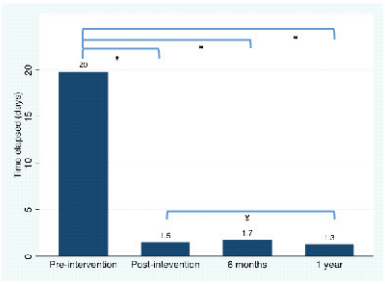

Fig. 2 Total Time Elapsed: Total Time is the number of days between the date the patient returned the Holter monitor and the date the referring physician received a final report. (*) p-values are < 0.001 for all three comparisons. (¥) p-values are non-significant (>1). A Bonferroni correction was used for all six pairwise comparisons.

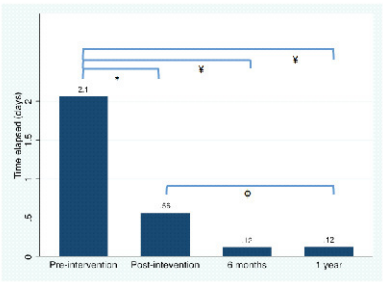

Fig. 3 Physician Interpretation Time Elapsed: Physician Interpretation Time is the number of days between the date the technician made the Holter data available to the physician and the date the physician signed a final report. (*) p-value is 0.01. (¥) p-values are < 0.001. (ϕ) p-values are non-significant (>1) for all pairwise comparisons. A Bonferroni correction was used for all six pairwise comparisons.

Table 1 Sustained improvement after intervention. See Methods for description of each time interval (e.g. "Total Time"). Each cell shows the mean elapsed time in days, followed by the standard deviation in parenthesis. All p-values reflect a Bonferroni correction for multiple comparisons. (*) These p-values represent the pairwise comparisons for B vs. C, B vs. D and C vs. D. The lowest p-value for any comparison is shown.

	A	B	C	D		
Elapsed time, days	**Pre-intervention**	**Immediately after intervention**	**6 months after intervention**	**1 year after intervention**	**p-value, A vs. B**	**p-values, B-D***
Total Time	19.8 (42.3)	1.5 (1.5)	1.7 (2.0)	1.3 (1.5)	< 0.001	> 1
Physician Interpretation Time	2.1 (5.0)	0.6 (1.0)	0.1 (4.0)	0.1 (0.4)	0.01	> 1
Patient Return Time	4.1 (3.8)	3.8 (2.7)	4.7 (7.8)	3.2 (2.2)	> 1	≥ 0.7
Technician Scanning Time	1.8 (4.7)	0.9 (1.5)	1.6 (4.3)	1.1 (1.5)	0.55	≥ 0.15

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